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Vol. VIII LANCASTER, PA., APRIL, 1918 No. 8

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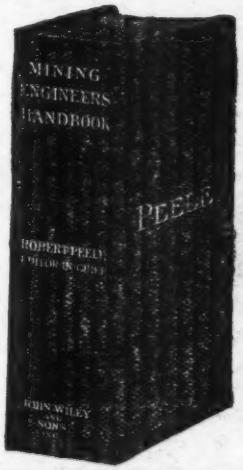

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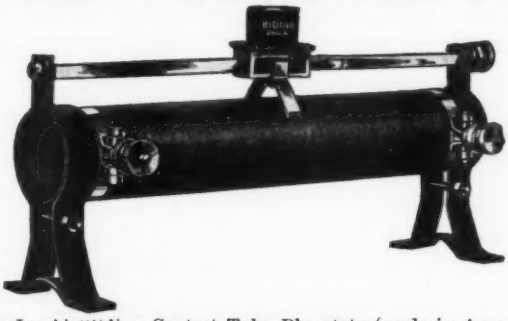

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TABLE OF CONTENTS.

Some Effects of the War on Engineering Education in the Pacific Northwest. By C. E. Magnusson 378
Reinforced Concrete Theory Without the Aid of Formulas. By Chas. A. Ellis 380
A Curious Misnomer in Mechanics. By Robert Fletcher 403
Discussion of "Some Observations Regarding the Methods of Teaching the Theory of Reinforced Concrete Design." 408
Discussions of "A New Point of View in Laboratory Work." 410
Committee on Education and Special Training 413
The Twenty-Sixth Annual Meeting 415
Editorial 417
Personals 417
College Notes 418
Book Reviews 419

SOME EFFECTS OF THE WAR ON ENGINEERING EDUCATION IN THE PACIFIC NORTHWEST.*

BY C. E. MAGNUSSON,

Acting Dean, University of Washington.

Only a very limited discussion of the effects of the War on engineering education can be attempted at this time, as the action is still in progress, with tendencies so uncertain as to make predictions useless even for the immediate future. For a comparative study of the tendencies in the several sections of the country, the following data from the University of Washington as a representative of the Pacific Northwest may be of interest.

(*a*) *Four-Quarter System.*—Shortly after the declaration of war, the University of Washington changed from the two-semester to the four-quarter system in order to speed up the training of students, especially in engineering and medicine. This summer a full quarter's work will be offered in civil, electrical, mechanical and chemical engineering.

(*b*) *New Courses.*—To meet the demand for technical training required in war service, new courses are given this year in shipdrawing, ship design, theory of aviation, airplane design, marine engineering, navigation, radio engineering, military French, sanitation, bacteriology, pharmacy and military science. A large number of lectures have been given by faculty members to the soldiers at Camp Lewis, American Lake Cantonment.

(*c*) *New Curricula.*—At the opening of the third quarter this year, regular four year curricula will be offered in military training, naval training and aviation, leading to commissions in the Army and Navy.

* This is the third of a series of articles on the effects of the war on engineering education being published in this magazine.

(*d*) *War Service.*—The preliminary *honor roll* of students and alumni in the Army and Navy contains fifteen hundred and eighty-four (1584) names. For lack of definite information, the *roll* has many omissions and the corrected figures will probably exceed two thousand (2,000). Most of the students who did not return to the university last fall are now in active military service.

As an example, may be mentioned that out of thirty-seven (37) men in last year's junior class in electrical engineering, twenty-two (22) are now serving either in the Army or the Navy.

Of the members of the engineering faculty, Major W. F. Allison is now "somewhere in France"; Captain C. C. More in the Ordnance Department in Washington; Captain H. G. Byers is with the 30th Engineers; Lieutenant H. L. Trumbull is in Washington; and Professors E. A. Loew and J. W. Miller are giving expert service in the nitrate industry and airplane manufacture respectively.

Military training has been increased to eight hours per week. Nineteen faculty members took special training in military science last spring and summer, and are now serving as captain-instructors in the Reserve Officers Training Corps, in which most of the students in engineering are enrolled.

(*e*) *Enrollment.*—Probably enrollment data are the most commonly used basis in making comparisons between educational institutions; and the following figures for the College of Engineering may be of interest:

Total enrollment, the year 1916–17 536
Total enrollment, first two quarters, 1917–18 363
Percentage of students in 1917–18, compared to the enrollment of 1916–17:

Seniors	Juniors	Sophomores	Freshmen	Total
70%	48%	45%	94%	68%

The enrollment for 1916–17 was slightly below normal.

REINFORCED CONCRETE THEORY WITHOUT THE AID OF FORMULAS.

BY CHARLES A. ELLIS,

Professor of Structural Engineering, University of Illinois.

Willie had an awful thirst,
But Willie is no more;
For what he thought was H_2O
Was H_2SO_4.

Whether the formula be rational or empirical, engineering or medical, it is a dangerous instrument except in the hands of experts. A formula frequently plays havoc with an engineering structure when used by a designer who knows not its history, meaning or limitations. But this is by no means the only instance when its use is hazardous. In the class-room, formulas should be given whatever prominence they deserve at the *end* of the course and not at the beginning, for the simple reason that they do more harm than good, when introduced earlier, by obscuring physical relations which should be visualized to the highest degree.

Gauss, one of the greatest physical mathematicians of the nineteenth century, remarked that many of the most celebrated mathematicians, Euler very often, Lagrange sometimes, had trusted too much to the symbolic calculation of their problems, and would not have been able to give an account of the meaning of each successive step in their investigations. Gauss said that he himself, on the other hand, could assert that at every step which he took he always had the aim and purpose of his operations before his eyes without ever turning aside from the way. "The same," he remarks, "might be said of Newton."

The standard text-books on the theory of reinforced concrete are probably the best examples of formulas running riot. The procedure for the investigation or design of a beam

usually follows this order: Algebraic symbols are given to the various data; the solution appears in the disguise of a group of a half dozen or more formulas; ever thereafter the numerical values are assigned to the algebraic symbols, the crank is turned and out pops the answer. The whole essence of the ultimate good resulting from mental discipline is lost; the fundamentals are obscured by the algebraic "substitution in the formula"; and what might have been an interesting and instructive problem falls to the level of a high-school exercise in algebra.

The formula method necessarily presents mathematical principles in generalities first, and particulars last. A history of any science will show that its development has been induced in the reverse order. A science should be presented to the student in the order of sequence most natural for the grasp of the human intellect, which can be no other than that by which all science is developed, namely, by progress from the particular to the general. Any other order is as confusing to the mind of the student as would be an attempt to interpret the plot of a movie drama, when the film is made to run backward.

The foregoing statements have been expressed by the present writer in a previous article;* and he has received several letters asking how a course in the theory of reinforced concrete might be conducted without the use of formulas, when using a text-book which adopted the formula method. An attempt to answer this question is the purpose of this paper.

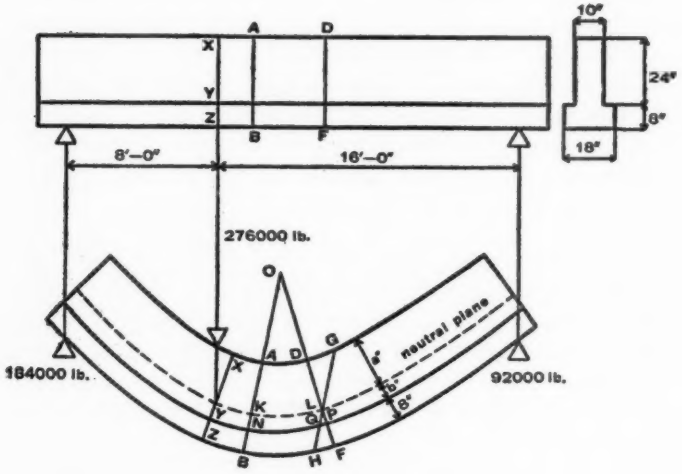
Hool's *Reinforced Concrete Construction*,* Vol. I, is used as a text. Several recitations are given to the discussion of

* "Graphical Calculus with Special Reference to Shear, Moment and Deflection Diagrams," *Journal of Western Society of Engineers*, April, 1917.

* The writer wishes it to be understood that this paper is in no sense to be construed as a criticism of this particular text-book. The fact that it is used in more than 80 institutions would discount 100 per cent. any criticism which he might offer.

properties of materials, as set forth in Part I; after which the following problem is assigned.

Fig. 1 represents a *homogeneous* beam supporting one concentrated load. What is the tensile or compressive unit-stress at X? At Y? At Z? Neglect weight of beam.



This course, given in the first semester of the senior year, is required of civil engineering students who completed their course in Mechanics of Materials in the first semester of their junior year. Consequently it is unnecessary to comment upon the solutions submitted at the following recitation. No doubt the situation recalls to the reader many similar harrowing experiences.

The members of the class are given an oral quiz upon the formula which all have attempted to apply. An elevation of the beam is sketched upon the blackboard; a horizontal line is drawn through the elevation and several points on the line are designated. As the crayon moves from one point to

another, a student is asked to name the symbols in his formula which represent variables. The exercise is repeated with a vertical line and perhaps with a diagonal line. Attention is also directed to the meaning of each symbol and the unit of measure. At the end of a rigorous quiz of thirty minutes the class is usually in a receptive mood and the following dictation is given.

The Bernoulli-Eulerian hypothesis or common theory of beams rests upon three principles which, when applied to a horizontal beam resisting vertical forces, not eccentric, may be stated as follows:

1. At any cross-section the sum of the horizontal tensile stresses equals the sum of the horizontal compressive stresses.

2. If two parallel lines are drawn close together on the side of the beam, perpendicularly to its length, before it is loaded; these lines, when the beam is loaded by any reasonable amount and bent by that loading, will still be straight as far as can be observed from careful examination; but they will converge to a point known as the center of curvature for that part of the beam.

3. The unit-stress is proportional to the unit-strain (unit shortening or lengthening) or $\frac{\text{unit-stress}}{\text{unit-strain}} = \text{modulus}$ *(measure) of elasticity (E), a ratio which varies for different materials.*

The first principle is a rational fact. The second and third principles are empirical assumptions which, although not strictly true, are sufficiently applicable in a reasonable design where the unit-stresses do not exceed the elastic limit of the material.

The same problem is assigned for the next lesson with the added instruction *that no formula is to be used;* but that the solution is to be based directly upon the three principles. The students are very much at sea. They attack the problem with about the same measure of success as attends an attempt to grasp a twenty four-inch sphere with one hand. Finally,

however, after *much* discussion and *little* guidance the following solution appears.

If parallel lines *AB* and *DF* (Fig. 1) are drawn upon the side of the beam before it is loaded, they will remain straight lines after it bends (second principle), but will converge and meet in some point *O*, if produced. The upper layers of the beam have been shortened; the lower layers have been lengthened; and a layer *KL*, situated somewhere between the top and bottom, remains unchanged in length. This layer separates the compressed and stretched portions and, being "strictly neutral," is called the neutral layer or neutral plane, the location of which is the first objective.

Draw *GLH* parallel to *AB*. Since in a practical beam the radii of the curved layers *AG*, *KL* and *BH* are very great when compared with the depth of the beam,* the lengths of the several layers between *AB* and *GH* may (without appreciable error) be considered equal. *DG* will represent the shortening which *AG* has undergone in its reduction to *AD*; *QP* will represent the stretch which *NQ* has endured in its elongating to *NP*; likewise *HF* will represent the stretch which *BH* has experienced in its lengthening to *BF*. If the several layers between *AB* and *GH* are taken as a unit of length, the corresponding length of that part of any layer between the line *DF* and *GH* will represent the shortening or lengthening of that layer in a unit of length. In other words, *DG* will represent the unit-strain for the top layer and *HF* that for the bottom layer, etc.

Since *DF* and *GH* are straight lines (second principle) intersecting at *L* on the neutral plane, it follows that the *unit-strain of any layer is proportional to the distance of that layer from the neutral plane*, or

$$\frac{a}{DG} = \frac{b}{QP} = \frac{b+8}{HF}.$$

* The representation of the deflection is grossly exaggerated in the figure. If the two lines *AB* and *DF* were drawn one inch apart and near the load where the curvature is the greatest, their intersection point *O* for a steel beam would be nearly one mile above the beam.

Since this beam is composed of a homogeneous material throughout, the modulus of elasticity is the same for all ratios of unit-stress to unit-strain (third principle).

Let f_c represent the unit-stress corresponding to the unit-strain DG,
f_s represent the unit-stress corresponding to the unit-strain QP,
and f_t represent the unit-stress corresponding to the unit-strain HF.

Then

$$\frac{f_c}{DG} = \frac{f_s}{QP} = \frac{f_t}{HF}.$$

But

$$\frac{a}{DG} = \frac{b}{QP} = \frac{b+8}{HF};$$

hence

$$\frac{f_c}{a} = \frac{f_s}{b} = \frac{f_t}{b+8}$$

or

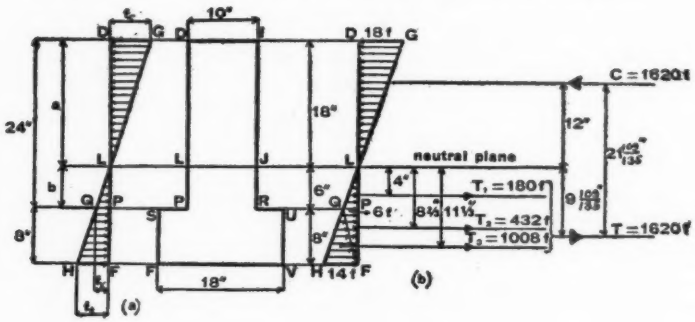
$$f_c : f_s : f_t :: a : b : b+8.$$

Therefore at any cross-section of a *homogeneous* beam the unit-stress (intensity of the stress) caused by bending is uniformly varying, with a maximum tensile unit-stress on the convex side and a maximum compressive unit-stress on the concave side; provided, of course, that the beam is so loaded that the unit-stresses in no case exceed the elastic limit of the material. Or in other words: Since the unit-strain varies as its distance from the neutral plane (second principle) and since the unit-stress varies as the unit-strain (third principle), it follows that for *homogeneous beams, the tensile or compressive unit-stresses vary as their distances from the neutral plane.*

The neutral plane may now be located by equating the sum of the tensile stresses to the sum of the compressive stresses (first principle). For convenience the conventional diagram

is redrawn in Fig. 2*a* where *GD*, *QP* and *HF* may represent the unit-stresses f_c, f_s and f_t respectively. The neutral plane is assumed to lie in the stem of the beam rather than in the flange, that is, the distance $DL = a$ is assumed to be less than 24 inches.

The cross-sectional area *DIJL*, which is 10 inches wide and a inches deep $= 10a$ square inches, is subjected to compressive



stresses. The intensity of stress is f_c pounds per square inch at *DI* and uniformly decreases to zero at *LJ*; hence the *average* intensity or the *average* unit-stress is $\frac{1}{2}f_c$ pounds per square inch. The sum of the compressive stresses therefore is

$$C = \tfrac{1}{2}f_c \; 10a = 5af_c \text{ lb.}$$

The tensile stress below the neutral plane on the area *LJRP* is $\frac{1}{2}f_s \; 10b$ lb.; on the area *SUVF* the tensile stress is $\frac{f_s + f_t}{2}$ 144 lb.

The sum of the tensile stresses therefore is

$$T = 5b\,f_s \text{ lb.} + 72(f_s + f_t) \text{ lb.}$$

From the first principle

$$C = T$$

or

$$5af_c = 5bf_s + 72f_s + 72f_t.$$

From the second and third principles

$$f_s : f_t :: b : b + 8 \text{ or } f_s = \frac{bf_t}{b+8}$$

and

$$f_c : f_t :: a : b + 8 \text{ or } f_c = \frac{af_t}{b+8}.$$

Therefore

$$5a\frac{af_t}{b+8} = 5b\frac{bf_t}{b+8} + 72\frac{bf_t}{b+8} + 72f_t$$

or

$$5a^2 = 5b^2 + 144b + 576,$$

but

$$a + b = 24.$$

Hence $a = 18$ inches and $b = 6$ inches.

If the neutral plane had been assumed to be below the top of the flange SU instead of above it, the solution would have given for b the value -6.

The neutral plane is now definitely located 18 inches below the top of the beam. Let f represent the unit-stress (tensile or compressive) for either layer *one inch* above or below the neutral plane (Fig. 2*b*). Then $18f$ is the compressive unit-stress on the top of the stem; $6f$ is the tensile unit-stress along the top of the flange; and $14f$ is the tensile unit-stress on the bottom of the flange.

The total compression on the area $DIJL$ is

$$C = \frac{18f}{2} \times 18 \times 10 = 1{,}620f \text{ lb.}$$

The tension on the area $LJRP$ is

$$T_1 = \frac{6f}{2} \times 6 \times 10 = 180f \text{ lb.}$$

The tension on the area *SUVF* will be considered in two portions. Let T_2 equal the sum of the unit-stresses represented by the triangle *QPF*, and T_3 equal the sum represented by the triangle *QHF*. Then

$$T_2 = \frac{6f}{2} \times 8 \times 18 = 432f \text{ lb.}$$

and

$$T_3 = \frac{14f}{2} \times 8 \times 18 = 1{,}008f \text{ lb.}$$

The total tension is $T = T_1 + T_2 + T_3$.

$$\begin{aligned} T_1 &= 180f \text{ lb.} \\ T_2 &= 432f \text{ lb.} \\ T_3 &= 1{,}008f \text{ lb.} \\ \hline T &= 1{,}620f \text{ lb.} = C \end{aligned}$$

The line of action of the sum (C) of the compressive stresses is through the centroid of the triangle *DLG*, 12 inches above the neutral plane. Similarly, T_1 acts 4 inches below the neutral plane; T_2, $8\frac{2}{3}$ inches, and T_3, $11\frac{1}{3}$ inches below the neutral plane.

The location of T is found as follows:

$$\begin{aligned} 180f \text{ lb.} \times 4 \text{ in.} &= 720f \text{ in.-lb.} \\ 432f \text{ "} \times 8\tfrac{2}{3} \text{ "} &= 3{,}744f \text{ " "} \\ 1{,}008f \text{ "} \times 11\tfrac{1}{3} \text{ "} &= 11{,}424f \text{ " "} \\ \hline 1{,}620f \text{ lb.} \qquad & (15{,}888f \text{ in.-lb.} \\ & 9\tfrac{1}{135}\tfrac{0}{9} \text{ in.} \end{aligned}$$

The line of action of T is $9\frac{1}{135}\frac{0}{9}$ inches below the neutral plane.

The two resultant stresses C and T form the resisting couple. The lever arm is $12 + 9\frac{1}{135}\frac{0}{9} = 21\frac{1}{135}\frac{0}{9}$ inches. The moment of this stress couple which resists the bending moment of the external forces is

$$M = 1{,}620f \text{ lb.} \times 21\tfrac{1}{135}\tfrac{0}{9} \text{ in.} = 35{,}328f \text{ in.-lb.}$$

The magnitude of f, which is the unit-stress at any cross-section on either side of the neutral plane and one inch from it, is found by equating the internal resisting stress couple to the moment of the external forces about the given cross-section and solving for f.

The moment of the external forces about the section XYZ (Fig. 1) is

$M = 184{,}000 \text{ lb.} \times 8 \text{ ft.} = 1{,}472{,}000 \text{ ft.-lb.} = 17{,}664{,}000 \text{ in.-lb.}$

Hence

$$35{,}328f = 17{,}664{,}000,$$

$$f = \frac{17{,}664{,}000 \text{ in.-lb.}}{35{,}328 \text{ in.}^3} = 500 \frac{\text{lb.}}{\text{in.}^2} \text{ or } 500 \text{ lb. per sq. in.}^*$$

The unit-stress varies uniformly as the distance from the neutral plane. Hence, if at section XYZ the unit-stress one inch from the neutral plane is 500 lb. per sq. in.; at X, or 18 inches above the neutral plane, the unit-stress is $18 \times 500 =$ 9,000 lb. per sq. in. compressive. Similarly at Y the unit-stress is 3,000 lb. per sq. in. tensile; and at Z, 7,000 lb. per sq. in. tensile.

* Much emphasis is given to the units of measure. For example, in the expression $C = \frac{18f}{2} \times 18 \times 10 = 1{,}620f$ lb., it should be noted that $\frac{18}{2}$ is a ratio; f represents lb. per sq. in. or $\frac{\text{lb.}}{\text{in.}^2}$; 18 and 10 express inches, hence the coefficient 1,620 represents in.^{2}. The term $1{,}620f$ represents in.$^2 \times \frac{\text{lb.}}{\text{in.}^2} =$ lb. Frequently, the units of measure are written directly below the equation thus.

$$M = 1{,}620f \times 21\,\frac{109}{135} = 35{,}328f$$

$$\text{in. lb.} = \text{in.}^2 \times \frac{\text{lb.}}{\text{in.}^2} \times \text{in.} = \text{in.}^3 \frac{\text{lb.}}{\text{in.}^3}$$

Students who previously found, by using the formula method, that the moment of inertia of the cross-section about the horizontal centroidal axis was 35,328 inches^4 will usually ask why the quantity 35,328 as here used expresses inches^3. This question gives an opportunity for some other student to make the reconciliation.

The method here given lays no claim to brevity. It is believed, however, that if the student is required to solve several problems by this method he will more quickly and thoroughly understand the "insides" of a beam than will be the case if he devotes his time to algebraic substitutions in a formula.* Little or no reference is made to the horizontal centroidal axis, moment of inertia or section modulus in this solution when used as an introduction to reinforced concrete theory.

It usually requires two class periods in which to develop the solution given above. The solution is never given in the form of a lecture; such procedure too frequently defeats its own purpose. Consistent, constant oral quizzing with an occasional suggestion is far more efficient in developing mental ability in the student.

At the close of the period in which the solution is completed, a second problem similar to the first, but with a different form of cross-section, is assigned. The solutions are submitted at the beginning of the next recitation, and the following problem is discussed in class.

A tension member consists of 3 steel eye-bars, each 10 in. wide and 1 in. thick. The center-to-center distance of pins is 50 feet. The diameter of the holes in the two outside bars is 7.1 inches; the diameter of the holes in the middle bar is 7 inches. The pins are a driving fit in the holes of the middle bar. What stress will each bar take if the member is pulling 130 tons, and what will be the center-to-center distance of the pins?

Call the modulus of elasticity of steel 30,000,000 lb. per sq. in. The middle bar must stretch 1/10 of an inch in 600 inches (50 feet) before the other bars begin to act. In each

* But if we must use a formula let us choose symbols which will not suggest a wrong interpretation. In a text which is open before me I find the formula $M = SI/c$, where c is explained as representing the distance from the neutral axis to the side of the beam furthest from that axis. The very fact that the symbol c is used suggests that it represents a constant for a beam of uniform cross-section. This is a very narrow and frequently misleading interpretation.

inch of the middle bar, the stretch or unit-strain is

$$\frac{1 \text{ in.}}{6{,}000 \text{ in.}} = \frac{1}{6{,}000}.$$

From the third principle

$$\frac{\text{unit-stress}}{\frac{1}{6{,}000}} = 30{,}000{,}000 \text{ lb. per sq. in.},$$

or the unit-stress is 5,000 lb. per sq. in.; and the total stress in the middle bar at the time when the outside bars begin to act is 5,000 lb. per sq. in. times 10 sq. in. = 50,000 lb.

At this point the three bars divide the remaining load of 210,000 lb., causing a unit-stress of 7,000 lb. per sq. in. in each outside bar and adding 7,000 lb. per sq. in. to the initial stress of the middle bar, making in all 12,000 lb. per sq. in. for that bar.

For the outside bars,

$$\frac{7{,}000 \text{ lb. per sq. in.}}{\frac{\text{total stretch}}{600 \text{ in.}}} = 30{,}000{,}000 \text{ lb. per sq. in.},$$

hence, their total stretch $= \dfrac{7{,}000 \times 600}{30{,}000{,}000} = 0.14$ in.

For the middle bar,

$$\text{the total stretch} = \frac{12{,}000 \times 600}{30{,}000{,}000} = 0.24 \text{ in.}$$

Hence 600.24 in. = center-to-center distance of pins.

The eye-bar problem solved during the recitation period paves the way for the following problem to be solved by the class and submitted at the following period.

A 12 in. × 12 in. timber is reinforced on two opposite sides with a 12 in. × ¼ in. steel plate for its full length of 30 ft., in such a manner that the wood and steel act together when under a tension of 158,400 lb.

How is the stress divided between the wood and steel? The solutions usually appear as follows:

Let

$$f_s = \text{unit-stress in steel}$$

and

$$f_w = \text{unit-stress in wood.}$$

Assume modulus of elasticity = 30,000,000 lb. per sq. in. for steel and 1,500,000 lb. per sq. in. for wood. If the two materials act together the unit-stretch must be the same for each, therefore

$$\frac{f_s}{\text{unit-stretch}} = 30{,}000{,}000; \quad \frac{f_w}{\text{unit-stretch}} = 1{,}500{,}000$$

or

$$\text{unit-stretch} = \frac{f_s}{30{,}000{,}000} = \frac{f_w}{1{,}500{,}000},$$

hence

$$f_s = 20 f_w.$$

The timber has 144 sq. in. of cross-section and the steel 6 sq. in.

$$144 f_w + 6 f_s = 158{,}400,$$

$$144 f_w + 120 f_w = 158{,}400,$$

$$f_w = 600 \text{ lb. per sq. in.},$$

$$f_s = 20 f_w = 12{,}000 \text{ lb. per sq. in.},$$

$$144 \times 600 = 86{,}400 \text{ lb.} = \text{stress in timber},$$

$$6 \times 12{,}000 = 72{,}000 \text{ lb.} = \text{" " steel},$$

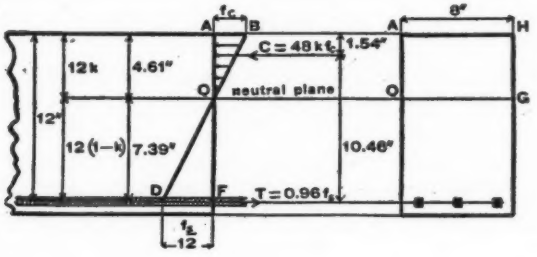
$$158{,}400 \text{ lb.} = \text{total stress.}$$

This problem brings out the important fact that if two materials *act together their unit-strains must be equal, consequently their unit-stresses are proportional to their moduli of elasticity.*

Paragraph 26 of the text, dealing with the behavior of re-

inforced concrete under tension, is reviewed; the reasons for neglecting the tensile stresses in the concrete below the neutral plane are brought out by discussion; and the class is ready to proceed with the illustrative problem, foot of page 56.

Illustrative Problem. What will be the resisting moment (M) for a beam whose breadth (b) is 8 in. with a distance from the center of the reinforcement to the compression surface (d) of 12 in., the area of steel section being 0.96 sq. in.?



$E_s = 30{,}000{,}000$ lb. per sq. in. $E_c = 2{,}500{,}000$ lb. per sq. in. $f_c = 500$ lb. per sq. in. $f_s = 16{,}000$ lb. per sq. in.

As in the homogeneous beam, the first task is to locate the neutral plane OG (Fig. 3). Let BA represent the shortening in a unit-length of concrete, or the unit-strain on the top surface; and DF the stretch in a unit-length of steel, or unit-strain. The *unit-strains* are proportional to their distances from the neutral plane (as in first problem), hence

$$12k : 12(1-k) :: BA : DF$$

or

$$k : 1-k :: BA : DF.$$

Let f_c represent the unit-stress in the concrete corresponding to the unit-strain BA; and f_s represent the unit-stress in the steel corresponding to the unit-strain DF.

The moduli of elasticity of concrete and steel are assumed

to be 2,500,000 and 30,000,000 lb. per sq. in. respectively; hence from the third principle,

$$\frac{f_c}{BA} = 2{,}500{,}000 \quad \text{and} \quad \frac{f_s}{DF} = 30{,}000{,}000$$

or

$$BA = \frac{f_c}{2{,}500{,}000} \quad \text{and} \quad DF = \frac{f_s}{30{,}000{,}000},$$

therefore

$$BA : DF :: f_c : f_s/12$$

or, if the distance BA is allowed to represent graphically the unit-stress f_c (not unit-strain) in concrete, DF will represent 1/12 of the unit-stress in the steel, or $f_s/12$. This step requires considerable elaboration lest the student, upon finding for f_s a value, let us say, of 12,000 lb. per sq. in., may conclude that the unit-stress in the steel is 1/12 of 12,000 = 1,000 lb. per sq. in.

According to the statement of the problem, concrete is 12 times more elastic than steel, *for stresses below the elastic limit.* A unit-stress which will shorten or lengthen a concrete bar 12/32 of an inch would, if applied to a steel bar of the same size and length, shorten or lengthen it only 1/32 of an inch. Or, if the changes in length of the two bars under stress were equal, the unit-stress in the steel bar would be 12 times that in the concrete bar. Again suppose that the neutral plane were situated 6 inches below the top of the beam, then the unit-strain BA in concrete at the top of the beam would equal the unit-strain DF in the steel rods, but the unit-stress in the steel would be 12 times greater than the unit-stress in the top layer of concrete.

Now

$$k : 1 - k :: BA : DF :: f_c : \frac{f_s}{12},$$

hence

$$k : 1 - k :: f_c : \frac{f_s}{12}.$$

The total compressive stress on the area $AOGH$ is

$$C = \tfrac{1}{2} f_c \text{ lb. per sq. in.} \times 8 \text{ in.} \times 12k \text{ in.} = 48kf_c \text{ lb.}$$

The steel rods are designed to carry the total tension.

$$T = f_s \text{ lb. per sq. in.} \times 0.96 \text{ sq. in.} = 0.96f_s \text{ lb.}$$

From first principle

$$C = T,$$

$$48kf_c = 0.96f_s,$$

$$f_s = 50kf_c.$$

Therefore

$$k : 1 - k :: f_c : \frac{50kf_c}{12}$$

or

$$k = 0.384,$$

$$AO = 12k = 4.61 \text{ in.},$$

hence

$$OF = 7.39 \text{ in.}$$

The last part of the problem as stated in the text frequently gives a wrong impression to the student. Referring to the definitions of f_c and f_s in paragraph 33 of the text, and then noting in the statement of the problem that $f_c =$ 500 lb. per sq. in., and $f_s = 16{,}000$ lb. per sq. in., the student frequently concludes that when the top layer of concrete is stressed 500 lb. per sq. in., the steel will simultaneously be stressed 16,000 lb. per sq. in.

Of course, the idea to be conveyed is that the compressive unit-stress in concrete and the tensile unit-stress in steel are not to *exceed* 500 lb. per sq. in. and 16,000 lb. per sq. in. respectively.

Assume that the steel is stressed to 16,000 lb. per sq. in., then

$$4.61 : 7.39 :: f_c : \frac{16{,}000}{12},$$

$$f_c = 832 \text{ lb. per sq. in.},$$

showing that the concrete would be over-stressed.

Assume that the concrete is stressed to 500 lb. per sq. in., then

$$4.61 : 7.39 :: 500 : \frac{f_s}{12},$$

$$f_s = 9{,}618 \text{ lb. per sq. in.},$$

showing that when the concrete has a compressive stress of 500 lb. per sq. in. on its top layer, the steel has a tensile stress of 9,618 lb. per sq. in.

The total compression is

$$C = \frac{500}{2} \text{ lb. per sq. in.} \times 4.61 \text{ in.} \times 8 \text{ in.} = 9{,}220 \text{ lb.}$$

The total tension is

$$T = 9{,}618 \text{ lb. per sq. in.} \times 0.96 \text{ sq. in.} = 9{,}230 \text{ lb.}$$

The slight discrepancy in the values of C and T is due to the fact that the value of k is correct only to three decimals.

The compression C acts 1/3 of $4.61 = 1.54$ in. below the top of the beam, hence the lever arm of the couple is $12 - 1.54 = 10.46$ in.; and the resisting moment is

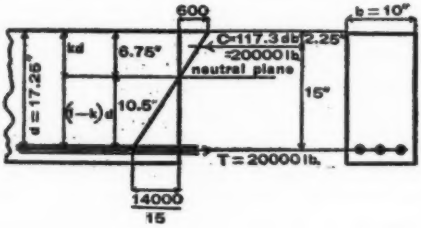
$$M = 9{,}230 \text{ lb.} \times 10.46 \text{ in.} = 96{,}500 \text{ in.-lb.}$$

A figure should be sketched for each problem and reference made to it continually. In this way the student's attention is directed to the problem *per se* rather than to algebraic manipulations.

The following problem is found at the foot of page 57.

Illustrative Problem.—A beam is to be figured to withstand a bending moment of 300,000 in.-lb. A 1:2:4 concrete will be used with $E_c = 2{,}000{,}000$ lb. per sq. in. and $f_c = 600$ lb. per sq. in. The pull in the steel is to be limited to 14,000 lb. per sq. in. Its modulus of elasticity E_s is 30,000,000 lb. per sq. in.

In this problem of design the amount of steel is not given. The neutral plane (Fig. 4) will be so located that the unit-stresses in concrete and steel will reach their respective allow-



able values of 600 and 14,000 lb. per sq. in. simultaneously. Note that concrete is considered 15 times more elastic than steel.

$$k : 1 - k :: 600 : \frac{14{,}000}{15}$$

or

$$k = 0.391.$$

The compression area is $0.391db$ sq. in. The lever arm is $d - (kd/3) = 0.87d$.

$$C = \frac{600}{2} \text{ lb. per sq. in.} \times 0.391db \text{ sq. in.} = 117.3db \text{ lb.},$$

$$M = 117.3db \text{ lb.} \times 0.87d \text{ in.} = 300{,}000 \text{ in.-lb.},$$

$$102 \text{ lb. per sq. in.} \times bd^2 \text{ in.}^3 = 300{,}000 \text{ in.-lb.},$$

$$bd^2 \text{ in.}^3 = \frac{300{,}000 \text{ in.-lb.}}{102 \text{ lb. per sq. in.}} = 2{,}930 \text{ in.}^3$$

If b is taken as 10 in., then

$$d^2 = 293 \text{ in.}^2 \text{ or } d = 17\tfrac{1}{4} \text{ in.}$$

The lever arm $= 0.87d = 15.0$ in.

$$T = \frac{300{,}000 \text{ in.-lb.}}{15.0 \text{ in.}} = 20{,}000 \text{ lb.}$$

The area of steel required $= \frac{20{,}000 \text{ lb.}}{14{,}000 \text{ lb. per sq. in.}} = 1.43$ sq. in.

At about this stage of the course, the impulsive student who was inclined to start a riot when the long-cherished formula was forbidden begins to "sit up and take notice." The emotional and volitional elements in his mental make-up subside and the intellectual faculties rise to the surface. This method at once appeals to the reason, the "noblest function of the mind." He is no longer required to memorize formulas which are too numerous to write upon his cuff.

Some enterprising student will express an interest in the tables and diagrams which appear in the latter part of the text. No explanation is made concerning them except that they contain answers to the problems. This information is sufficient. In a written quiz given near the end of the course, the problems are stated in their most general terms: *i. e.*, symbols are used in place of numerical values, and the formulas are thereby developed. The student is required to make also some addition to the diagrams. For example, in diagram 1, page 223, he is required to add the lines which represent 2,100 and 900 respectively. Throughout the course in design, given the following semester, the diagrams and tables are used continually, although not exclusively.

. . . . . .

Web Reinforcement.—As the class understands that concrete is not suitable for resisting tensile stresses, the topic of reinforcement for diagonal tension due to shear is easily introduced. There are several ways by which the student may be convinced that diagonal tension exists, whenever he hesitates to put confidence in the mathematical analysis of the lines of principal stresses. The view of a thin web-plate in a girder which has been strained with ultimate loads is an excellent example. The class may observe a small square, which has been drawn upon the edge of a large rubber eraser, distort into a rhombus as the rubber is bent. The subject of

equal intensities of horizontal and vertical shearing stress for any point is discussed.

The illustrative problem on page 116 of the text will now be considered and may be stated as follows:

Design a beam to span 10 feet and to support 600 lb. per linear foot (not including weight of beam). The allowable compressive unit-stress for concrete, and the tensile unit-stress for steel are 650 and 16,000 lb. per sq. in. respectively. Ratio of moduli of elasticity is 15.

The allowable bond unit-stress is 80 lb per sq. in.; the allowable shearing unit-stress without web reinforcement is 40 lb. per sq. in., with web reinforcement 120 lb. per sq. in.

Assume 85 lb. per linear foot for the weight of the beam. The maximum bending moment is 103,000 in.-lb.

Make a sketch similar to the diagram in Fig. 4, differing of course in numerical values.

$$k : 1 - k :: 650 : \frac{16{,}000}{15}, \quad k = 0.378.$$

The compression is

$$C = \frac{650}{2} \times 0.378db.$$

The resisting moment is

$$C \times 0.874d = 107.4bd^2 = 103{,}000,$$

$$bd^2 = 960.$$

Assume $b = 7$ inches,

$$d^2 = \frac{960}{7} = 137, \quad d = 11.7 \text{ inches}.$$

We shall design the beam 7 inches wide and $11\frac{1}{2}$ inches from the top surface to the horizontal reinforcing, and allow 13 inches for the total depth. The neutral plane is

$11.5 \times 0.378 = 4.35$ inches below the top of the beam.

The distance between C and T, or what may be called the

effective depth is

$$11.5 - \frac{4.35}{3} = 10.05 \text{ in.}$$

The maximum tension is

$$\frac{103{,}000}{10.05} = 10{,}300 \text{ lb.}$$

The steel area required is

$$\frac{10{,}300}{16{,}000} = 0.64 \text{ sq. in.}$$

We shall select three $\frac{1}{2}$-in. sq. bars having a cross-sectional area of 0.75 sq. in. At 150 lb. per cu. ft., the weight per linear foot of the beam is

$$\frac{7 \times 13}{144} \times 150 = 95 \text{ lb.}$$

The assumed and computed weights (85 lb. and 95 lb.) do not differ materially, but we shall assume 696 pounds per linear foot or 58 pounds per linear inch for the total load. The steed area used in the design is about 20 per cent in excess of the amount required; on the other hand we have taken the depth of the beam to the reinforcing as 11.5 inches instead of 11.7 inches. On account of these differences it may be well to review our design.

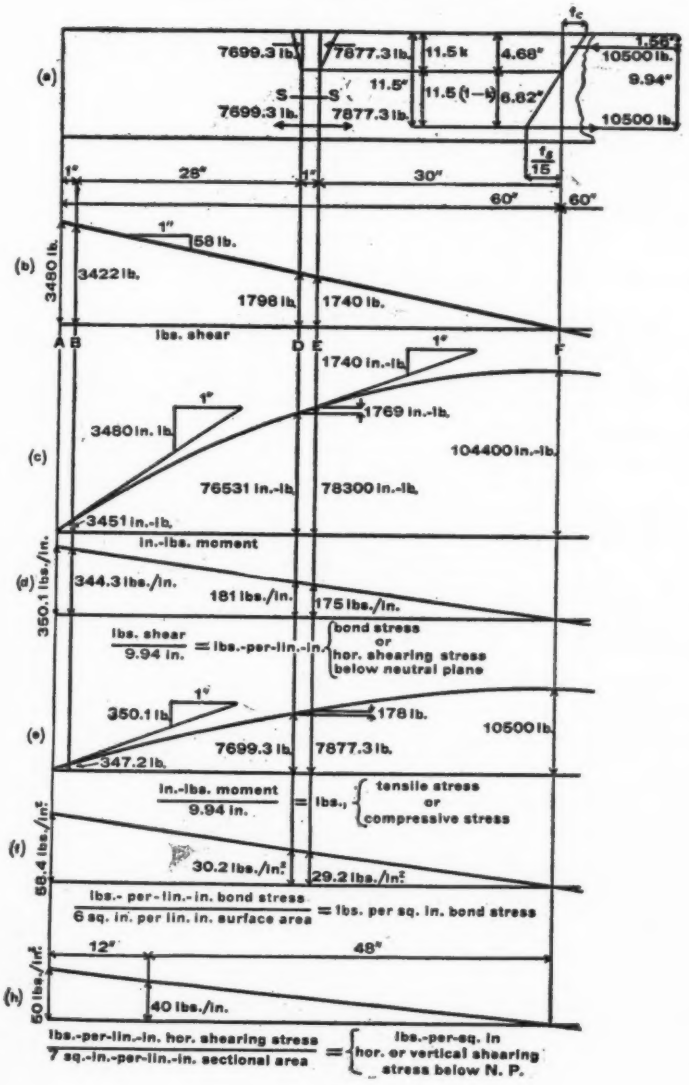
From Fig. 5*a*

$$k : 1 - k :: f_c : \frac{f_s}{15} \text{ or } f_s = \frac{(1-k)15f_c}{k},$$

$$C = \frac{f_c}{2} 11.5k7 = 0.75f_s = \frac{0.75(1-k)15f_c}{k},$$

$$40.25k^2 + 11.25k = 11.25,$$

$$k = 0.407.$$


(a)
7699.3 lb.
7877.3 lb.
11.5 k
4.68"
11.5"
11.5 (1 − k)
6.62"
S
S'
7699.3 lb.
7877.3 lb.
1.58"
10500 lb.
9.94"
10500 lb.
f_c
f_s / 15
1"
28"
1"
30"
60"
60"
(b)
3480 lb.
1"
58 lb.
3422 lb.
1798 lb.
1740 lb.
lbs. shear
A B
D E
F
1740 in.-lb.
1"
(c)
3480 in. lb.
1"
1769 in.-lb.
104400 in.-lb.
76531 in.-lb.
78300 in.-lb.
3451 in.-lb.
in.-lbs. moment
(d)
350.1 lbs./in.
344.3 lbs./in.
181 lbs./in.
175 lbs./in.
lbs. shear / 9.94 in. = lbs.-per-lin.-in. { bond stress or hor. shearing stress below neutral plane
(e)
1"
350.1 lb.
178 lb.
10500 lb.
7699.3 lb.
7877.3 lb.
347.2 lb.
in.-lbs. moment / 9.94 in. = lbs., { tensile stress or compressive stress
(f)
58.4 lbs./in.²
30.2 lbs./in.²
29.2 lbs./in.²
lbs.-per-lin.-in. bond stress / 6 sq. in. per lin. in. surface area = lbs. per sq. in. bond stress
12"
48"
(h)
50 lbs./in.²
40 lbs./in.
lbs.-per-lin.-in. hor. shearing stress / 7 sq.-in.-per-lin.-in. sectional area = { lbs.-per-sq. in hor. or vertical shearing stress below N. P.

The neutral plane is

$11.5 \times 0.407 = 4.68$ in. below the top of the beam.

The effective depth is

$$11.5 - \frac{4.68}{3} = 9.94 \text{ in.}$$

The maximum bending moment is

$$\frac{696 \times 10 \times 10 \times 12}{8} = 104{,}400 \text{ in.-lb.}$$

$$T = \frac{104{,}400}{9.94} = 10{,}500 \text{ lb.}$$

At the section of maximum bending moment, the unit-stress in the bars is

$$\frac{10{,}500}{0.75} = 14{,}000 \text{ lb. per sq. in.,}$$

$$4.68 : 6.82 :: f_c : \frac{14{,}000}{15}.$$

Hence the unit-stress in the concrete at the top of the beam is

$$f_c = 641 \text{ lb. per sq. in.}$$

$$C = \frac{641}{2} \times 4.68 \times 7 = 10{,}500 \text{ lb.} = T \quad \text{(a check).}$$

(Continued.)

A CURIOUS MISNOMER IN MECHANICS.

Anent the "Conical Pendulum" and "Centrifugal Force."

BY ROBERT FLETCHER,

Director of the Thayer School of Civil Engineering, Dartmouth College.

A distinguished, beloved and much lamented former member of this Society once wrote as follows* in criticizing the writer of a text-book entitled "Mechanics for College Students":

"He is discussing the motion of a conical pendulum whose moving ball describes a horizontal circle. He says:

"'Three forces are acting upon the moving ball: gravitation, the tension in the pendulum-thread or rod, and the centrifugal force which balances the other two.'

"What will become of students who stumble over such a statement as that? Will they ever see clearly that the ball is acted upon by only two forces which do not balance; and that, consequently, the ball is not moving under balanced forces. Centrifugal force is a big bugbear. In the above problem there is no centrifugal force, and there should be no use for the expression."

The erroneous part of this statement was due to the persistence of the author in his idea of looking only at one side of the equation, sometimes averring that we are not concerned with the other body or other side. Consequently the principle known as Newton's third law of motion ("To every action there is always an equal opposite and simultaneous reaction") was systematically slighted. But, of course, in his denouncement of the common conception (or misconcep-

* In *Harvard Engineering Journal.*

tion) of "centrifugal force," he was entirely right. There is no such *force* or primary action. It is a *reaction* or resistance which the *inertia* of the body opposes to the incessant deflection from a tangential path. Inertia is not a force but simply a property of the body. By the first law of motion the ball would fly off on a tangent (straight) line, if not constrained by the central force due to the suspending and restraining cord or link.

These elementary considerations are reviewed here because we constantly find in text-books and technical articles statements on this point which at least are hazy and misleading, and sometimes quite erroneous.* The present writer presents the case of the *revolving balls* or Watt governor as follows:

A heavy ball, suspended from a point above by a cord or link, is drawn to one side by a pull, P, acting through a horizontal cord. Here is statical equilibrium of three forces: the weight, W, the tension, T, on the link and the pull, P. The horizontal component of $T = W \tan \theta = P$. The vertical component of $T = T \cos \theta = W$. Now suppose a horizontal impulse is given to the ball so that it revolves around a vertical line, always at a height, h, below the point of suspension and at a constant distance r from the vertical axis; the velocity being such that the aspect (or vertical projection) of the ball and suspending link is the same as before, although P is no longer acting. In this case the equilibrium is not *statical* but *dynamical*. Some deviating action has replaced P; what is it? It is the *centrifugal reaction* which opposes the *centripetal* force, $W \tan \theta$; it has no existence until the latter acts when the velocity of revolution is established; that is to say, it is coexistent but not preëxistent, be-

* If "to err is human," to be inconsistent is equally human, for all of us. Our genial and revered author, in his excellent textbook, which the writer has used with much satisfaction, has a paragraph farther on beginning with the words "The centrifugal force . . .," in spite of his previous righteous indignation at that term. Of course he constantly deals *with reactions*, while usually avoiding the use of the word.

cause no action is possible without an equal and opposite reaction (here the resistance or reaction of inertia).

This brings us to the point of criticism of the term *conical pendulum*, almost universally applied to the revolving ball or balls. In the concepts of mechanics *it certainly is not a pendulum.* It has no property in common with a pendulum, excepting the fact of suspension. The pendulum has variable motion in a vertical plane; an oscillation between opposite points of rest, where the acceleration is a maximum; between which is the lowest point of maximum velocity and consequent zero of acceleration. Per contra the revolving ball has *uniform* motion in a circular orbit. The pendulum is acted upon by the constant force of gravity, while the revolving ball moves under the action of forces in balance—dynamical equilibrium.

Let us note the fact that a heavy weight, held suspended from the hand by a cord, and then made to revolve in its orbit like the ball of the Watt governor (the cord describing a cone), furnishes a simple and beautiful illustration of Newton's three fundamental laws of mechanics. The most obvious is the law of action and reaction (third law, so called) just demonstrated—the centripetal or *central* force and its opposite. The next principle (so-called second law) that change of motion is proportioned to the impressed force and takes place in the line of action of that force—this is most apparent in the normal acceleration, or motion compulsory towards the center, that is change of motion along the radius. This—when a change is forced in the orbital velocity—is felt to be proportional to the central pull or attraction. The first law—that a body always moves in a straight line with uniform motion unless compelled by some force to change that direction or velocity—is indirectly exemplified because the orbital path is possible only through the constraint of the horizontal component of the cord tension, $W \tan \theta$. If we let go the cord, central pull and inertia reaction cease simultaneously, and the body goes off in a tangent plane. Popular misconcep-

tion on this point appears in the statement that a person is "thrown out" of a wagon or automobile. That is a great mistake. When the vehicle suddenly swerves on a sharp curve and the person fails to hold on to the seat, he is not *thrown out* but *left out*. The wagon *leaves him*. He is not *even* left *behind* because he keeps going in the original direction, until he strikes the ground.

When the uniform velocity of revolution of the ball in its orbit is established, evidently *no work is done*, since there is no *change* in the momentum or in the energy. This is not true of the pendulum which is incessantly storing work in its descent and giving up that work against the force of gravitation, in its ascent.

A distinguished writer and teacher* of mechanics gives the following fundamental equation:

$$\Sigma P\delta p - \Sigma m\frac{d^2s}{dt^2}\delta s = 0 \text{ or } \Sigma P\delta p = \Sigma m\frac{d^2s}{dt^2}\delta s,$$

in which P is any impressed force; δp the displacement of its point of application in the direction of P, m the elementary mass acted upon by P, and δs its displacement, while d^2s/dt^2 is its acceleration. Which, being interpreted, is: The algebraic sum of the work of all the impressed forces and of the work of the *reactions* of all the elementary or constituent masses of the body is always equal to zero. Briefly it is an algebraic statement of the third law. Of this he says: "This single formula is the one fundamental equation which embraces in its discussion the whole of physical and mechanical science."

Hence those who claim that in mechanics we may consider only one side of the equation and ignore the other side are departing from sound doctrine. It was with regret that the writer (in friendly correspondence only) felt obliged to point out the misconception in regard to the revolving balls, which

* W. H. C. Bartlett, formerly professor of "natural and experimental philosophy" at the U. S. Military Academy, West Point, N. Y.

led to the statement that the forces acting upon them are not in balance. Inevitably the fundamental principle so clearly stated by Bartlett must apply, and be kept constantly in mind. In statics, since there is no change of motion, and no inertia developed, the second term disappears. In dynamics the second term must always enter into the discussion when change of motion occurs.

All this is very elementary and may seem impertinent to some readers; but it is a point upon which too little emphasis is placed by some teachers. The writer knows by experience that some students fail to grasp it unless it is reiterated and thoroughly exemplified by problems and illustrative practical cases. We all know how many hazy conceptions and misuse of mechanical terms appear in print. There is need of more insistence upon clean-cut definitions and clear statement of fundamental concepts.

If the term "centrifugal force" could be abandoned by common consent and "centrifugal reaction" substituted, very much misconception would be avoided. Really there is *never* centrifugal *force* but *always* centrifugal *reaction.* The *"force"* is *centripetal* only.

Certainly it is not justifiable from the point of view either of science or common sense to apply the term *pendulum* to that which has none of the properties of a pendulum according to correct mechanical definition.

DISCUSSION OF "SOME OBSERVATIONS REGARDING THE METHODS OF TEACHING THE THEORY OF REINFORCED CONCRETE DESIGN" BY PROFESSOR A. B. McDANIEL IN ENGINEERING EDUCATION, VOL. VIII, NO. 4, 1917.

BY W. K. HATT,

Purdue University.

Professor McDaniel tells us that the teacher should "utilize every possible device to require the student to exercise his mental processes and shun all rule-of-thumb methods." The present writer has recorded his views concerning the teaching of reinforced concrete design in a paper before the American Concrete Institute, as printed in the *Transactions* for the year 1916, where he has called attention to the difficulty of teaching Reinforced Concrete Design because of the conventional nature of the standard equations which Professor McDaniel uses for the training of the student mind in rational processes.

It is the practise of the present writer to accompany this fundamental theory of reinforced concrete with experiments in the laboratory. For instance, a reinforeed concrete beam is tested and the amount of deformation both in the steel and in the concrete is measured by the student who, then, with these deformations and the modulus of elasticity, computes the stresses in the steel and the concrete. He might now apply the Socratic method to Professor McDaniel and ask him how he would explain the fact that whereas Professor McDaniel's fundamental equations would predict a stress of 16,000 pounds per square inch in the steel, the student has measured less than 10,000 pounds per square inch, and why the moment of resistance as computed from the steel stresses at the design load is only 60 per cent. of the external moment.

I think Professor McDaniel would have to explain to the student that the equations and diagrams are conventional and he would have to discuss the stage of flexure at which his equations become representative of facts, before he could meet the needs of an inquiring mind.

The more we bring the student into contact with the real mechanism of physical deformation in actual materials before proceeding to conventions or abstractions, the more likely we are to reach one of the ends of education, namely, to develop power of original thought.

DISCUSSION OF "A NEW POINT OF VIEW IN LABORATORY WORK," BY W. L. UPSON, IN "ENGINEERING EDUCATION," VOL. VIII, NO. 5, 1918.

BY S. A. MOSS,

General Electric Co.

Mr. Upson's general scheme appeals to me very much. I think it has one very important advantage which Mr. Upson does not tabulate. This is the fact that a man who is not fitted to become an electrical engineer probably would not be successful in the sort of laboratory work which is proposed.

I do not believe that a man can be taught to do "individual creative work" by an amount of education. A natural aptitude for such work will be disclosed by the course which Mr. Upson gives. I believe, however, that many men will be found who will make no start at all at such work. They will want to know just what they should do next, demand complete directions as to how they should work, remark "I did not know that is what you wanted" if specification is made of something they might have done and did not, and so on throughout the well-known list of excuses.

Such men may be perfectly good at other kinds of work, but lack aptitude to do the individual creative work in electrical engineering which Mr. Upson so well discusses. I believe the cases Mr. Upson mentions of lack of enthusiasm are really lack of aptitude. It seems to me that it can never be developed or "instilled" in such cases.

It seems to me, therefore, that such laboratory work could easily be made a deciding factor as to whether or not a man is fitted to become an electrical engineer. Such a laboratory course is of course admirable for a man who can succeed in it.

It cannot produce the ability to do "individual creative

work," but it can develop such ability when it previously exists. If a man fails in such a course it will probably be because he lacks creative ability in this direction. He should then be directed to some pursuit other than electrical engineering.

BY BARRY MacNUTT,
Lehigh University.

Professor Upson's article in the January *Engineering Education* was read with a great deal of interest and pleasure. He has unquestionably the right idea and it is gratifying to find someone who has broken away from the traditional laboratory methods which have so devitalized laboratory work in colleges and technical schools.

A few years ago I tried the experiment of conducting our sophomore laboratory course in physics, covering Mechanics, Heat, Electricity, Magnetism, Light and Sound, in a manner very similar to Prof. Upson's. Instead of giving the students a fixed number of experiments per term, with cut-and-dried directions as to exactly how they were to perform each experiment—the apparatus required, diagram of connections, work to be done, number of observations necessary, etc. (thus relieving the student of all necessity to think)—we gave them a series of "problems" to be solved in the laboratory. Some of these "problems" were as follows:

Locate the center of mass of this belt pulley.

Standardize this aneroid barometer.

How much heat per day is absorbed by the refrigerator in the laboratory?

Determine the eutectic point of sugar.

Find the efficiency of an electric heater for heating water.

How much of a temperature drop outdoors today would be required to condense some of the water vapor in the air?

Find how long a piece of this wire would be required for a resistance of 1,000 ohms at 20° C.

Construct a shunt for this galvanometer, so that it will be one tenth as sensitive, etc.

The students were given these "problems" and turned loose in the laboratory where they were given, within limits, as much time as they desired to solve them. The sections numbered from sixteen to twenty men per instructor.

The experiment was not altogether successful. We found that students of sophomore age were not mature enough (with a very few exceptions) to profit by a course in which there was no rigorous constraint. They did not take sufficient interest in the course to try to get all out of it that it contained and their work tended towards slovenliness and "soldiering." It did, however, make them think for themselves, so that the course cannot be said to be an entire failure.

In our Sophomore Laboratory Course we have gradually slipped back to a compromise between the above revolutionary method and the cut-and-dried formalism of the typical physics laboratory course.

At present, the Sophomores are held to a definite number of experiments per term but the notes on these experiments are cut down to a minimum, and the students are made to rely on their own resourcefulness as much as possible. They do not, perhaps, have to think for themselves quite as much as they did, but they are more industrious and possibly learn better to be precise and methodical.

For some time I have been considering the advisability of trying the revolutionary method in our junior course in advanced electrical measurements. Professor Upson's article has decided me to run this course according to the method he pursues at Union College.

COMMITTEE ON EDUCATION AND SPECIAL TRAINING.

The Committee on Engineering Education of the Council of National Defense recommended to the Secretary of War, on August 17, the creation in the War Department, of a board to take charge of the technical training of enlisted men. The matter was referred by the Secretary to the General Staff and Capt. Lane assigned to work with the committee in regard to it. The matter was under consideration by the General Staff for a number of months. Upon February 13, the Secretary of War authorized the following announcement:

"With a view to mobilizing the educational institutions of the country and their faculties for special training, there has been created in the War Department a 'Committee on Education and Special Training.'' Associated with this committee will be five civilian educators, known as an advisory board of educators.

"The committee will be composed of Col. Hugh S. Johnson, deputy provost marshal-general; Lieut. Col. Robert I. Rees, of the General Staff; and Maj. Grenville Clark, of the Adjutant-General's Department.

"Advisory Members of Committee."

"The five advisory members of the committee, whose selection has been approved by the Secretary of War, are:

"Dr. Charles R, Mann, of the Carnegie Foundation for the Advancement of Teaching, and the Massachusetts Institute of Technology.

"Dr. James R. Angell, of Chicago, dean of the faculties of the University of Chicago.

"Mr. J. W. Dietz, of Chicago, director of education, Western Electric Company, president of the National Association of Corporation Schools.

"Mr. James P. Munroe, of Boston, a member of the Federal

Board for Vocational Education (which appointment will include the interests of the trade schools and schools of secondary grade).

"Dr. Samuel P. Capen, of Washington, specialist in higher education.

"In these appointments it is felt that the entire educational field has been covered, since Dr. Mann is representative of engineering schools, Dr. Angell is representative of academic colleges and universities, and Mr. Dietz is from the field of schools conducted by industrial concerns. The committee will be authorized to call in from time to time other educators for consultation and assistance.

"Functions of the Committee.

"The functions of this committee will be to mobilize the country's schools and colleges behind the Army. It will encourage and arrange for the technical education of men needed by the several branches of the Army, particularly the Ordnance Bureau, the Signal Corps, and the Engineers. In a degree the educational institutions are already rendering patriotic service to the government, but it is planned that there shall be a systemization of their efforts and that their facilities for technical training shall be fully utilized."

Delayed Classification of Instructors.

The following telegram was received by the Secretary of the Society in reply to a request for exact information in regard to instructors in the special technical courses being given to soldiers under the direction of this committee:

"Instructor certified by institutions engaged in war work as essential to carrying on the work may enlist in Enlisted Reserve and be placed in Class V when his application and certificate are approved by this Committee."

"(signed) C. R. MANN."

TWENTY-SIXTH ANNUAL MEETING AT NORTHWESTERN UNIVERSITY, EVANSTON, ILL., JUNE 26–29.

Registration and Information.

The place of registration and general information in connection with rooms, meals, baggage, etc., will be in one of the dormitory buildings. The general registration, post office, etc., will be in Swift Hall of Engineering.

Meeting Place.

All meetings of the Society will be held in the main lecture room Swift Hall of Engineering. Meetings of the Council and all committees will be held in adjoining rooms.

Meals.

Meals will be served in the dining rooms of certain of the fraternity houses.

Recreation and Excursions.

The dormitories and fraternity houses at which members are to live and Swift Hall of Engineering at which the formal meetings of the Society will be held are all on the shore of Lake Michigan in well-shaded grounds. The Local Committee hopes that its guests will, as a rule, use the late afternoon hours to get acquainted with each other in the open air on the shore of the lake and the Committee will endeavor to make it pleasant for them to do so. There will be opportunities for swimming and other out-of-door activities. As indicated in the program there will be an informal meeting at the Gymnasium on Wednesday evening and both the afternoon and evening of Friday will be devoted to an excursion on the north shore and a dinner at one of its most pleasant resorts, Ravinia Park.

The following announcements should be inserted in the proper places in the program.

Wednesday, June 26, 8:00 p.m. Annual Mixer Meeting at the Northwestern Gymnasium.

Friday, June 28. The afternoon will be devoted to an excursion by electric cars to the United States Naval Training Station at Great Lakes, Ill. On the return trip a stop-over will be made at Ravinia Park for the annual dinner of the Society at 6:30 p.m., to be followed by the presidential address and other speakers.

General Committee: Director John F. Hayford, Chairman, Professors H. S. Philbrick, O. H. Basquin, W. C. Bauer.

Committee on Rooms and Meals: H. S. Philbrick, Chairman, W. C. Bauer, W. F. Bryan, K. K. Smith.

Committee on Relations with Non-Members and Entertainment of Visiting Ladies: O. H. Basquin, Chairman, H. S. Philbrick, W. F. Bryan.

Committee on Arrangements at Swift Hall of Engineering: John F. Hayford, Chairman, W. H. Burger, K. K. Smith, M. R. Hammer.

Committee on Afternoon Excursions and other Social Affairs: W. C. Bauer, Chairman, W. H. Burger, K. K. Smith.

EDITORIALS.

The Report of the Joint Committee on Engineering Education.—We understand that the report of the Joint Committee on Engineering Education, which was appointed through the efforts of this Society in 1907, is now in the hands of the printers and will be available for distribution before the annual meeting. This report is the outcome of a long study of engineering schools. It has been discussed at our annual meetings by Dr. C. R. Mann, the investigator in charge. The completed report will undoubtedly call forth much discussion and favorable comment. It forecasts the type of engineering schools best adapted to meet the needs of this country in the training of engineers and representing, as it does, not only long years of study, but the efforts of many men, it should be recognized as an authority and point the way to the advancement and development of engineering education during and after the war.

A Curious Misnomer in Mechanics.—Director Robert Fletcher of the Thayer School of Dartmouth College has, in this number of ENGINEERING EDUCATION, an interesting article on "A Curious Misnomer in Mechanics." There is more in the article than appears in the title since it is also an exposition of the necessity for greater clearness and more appropriate use of terms in mechanics. The following quotation should be taken to heart by all teachers of engineering students:

"We all know how many hazy conceptions and misuses of mechanical terms appear in print. There is need of more insistence upon clean-cut definitions and clear statements of fundamental concepts."

PERSONALS.

Mr. Milo S. Ketchum, President of the S. P. E. E., dean of the college of engineering, University of Colorado, has been

granted a leave of absence by the regents of the university to accept a position as an assistant director, acting under Mr. D. C. Jackling, director in charge of the construction of U. S. government explosives plants.

Dean Ketchum will be located at Charleston as assistant director in charge of the construction of the explosives plant that is being constructed near that place. His address will be U. S. Government Explosives Plant "C," Nitro, West Virginia.

COLLEGE NOTES.

Throop College of Technology of Pasadena has adopted the following important plans with a view to increasing the effectiveness of the College in war work:

1. The introduction of a course in ship construction and ocean transportation to be required of all juniors and seniors in the college. This course will be inaugurated by Professor Frank P. McKibben, of Lehigh University, now serving under the United States Shipping Board. The course will be supplemented by visits to shipyards in Los Angeles harbor.

2. The speeding up of the work of the present senior class and setting forward the date of their graduation from June 4 to April 7.

3. The speeding up of the work of the present junior class continuing their instruction through the coming summer, and graduating them September 15, 1918, instead of in June, 1919.

4. The admission of a special freshman class on February 4, 1918, and continuing their instruction through the summer so as to give them a year's work by the opening of the fall semester, 1918, at which time they will become regular sophomores. It is anticipated that a good-sized class will enter at the mid-year.

BOOK REVIEWS.

Mathematical Tables for Classroom Use. By MANSFIELD MERRIMAN. First Edition. John Wiley and Sons, 1915. $5 \times 7\frac{1}{2}$. 67 pages.

These four-place tables have been taken from the American Civil Engineers Pocket Book and will be useful to the student in shortening his time spent in laborious computations. In this small volume are found thirty-five tables with the explanations for their use and with remarks on the degree of precision to be expected in interpolated tabular values.

F. A. F.

Infinitesimal Calculus. Section I. By F. S. CAREY, Professor in the University of Liverpool. Longmans, Green and Co. 1917. $5\frac{1}{2} \times 8\frac{1}{2}$. Cloth. 144–xiv pages.

The ideas of range and sequence have been introduced early in the book and used throughout. The notation of single and fully barbed arrows is used to express the limits of sequences with a careful distinction as to their respective uses. The book will be found rich in suggestions to the teacher who wishes to see these methods applied to an elementary textbook.

F. A. F.

Theory and Operation of Direct Current Machinery. By CYRIL M. JANSKY, Associate Professor of Electrical Engineering, University of Wisconsin. McGraw-Hill Book Co., Inc. 1917. $6 \times 9\frac{1}{4}$. 285 pages.

This book is suitable for persons who wish to gain a broad knowledge of the principles and operation of direct current machinery in the shortest possible time. About equal space is allotted to the following phases of direct current machinery: the fundamental theories and elements underlying direct current apparatus, the construction of generators and motors with the theory upon which the construction depends, and the operation of generators and motors. Chapters pertaining to special applications, batteries automatic starters, etc., as

found in most electrical texts, are omitted. The entire book is devoted to direct-current dynamos. It gives the reader a very plain and elaborate presentation of direct current machines with the involution of only elementary mathematics.

J. E. K.

Kinematics of Machinery. By ARTHUR WARNER KLEIN, M. E. Professor of Mechanical Engineering, Lehigh University. McGraw-Hill Book Co. Inc. 1917. 6 × 9, 227 pages. Cloth.

The major part of this book deals with the graphical method for the solution of machine kinematics. The explanations are clear and fully developed. Numerous illustrations assist in making the subject plain to the student.

Those points which have been deemed unnecessary for an elementary course are omitted from the text proper and grouped in an appendix.

It is a book equally valuable to both the student and practising engineer.

W. E. J.

Position Wanted.—931. Teacher of Electrical Engineering desires change after July 1.

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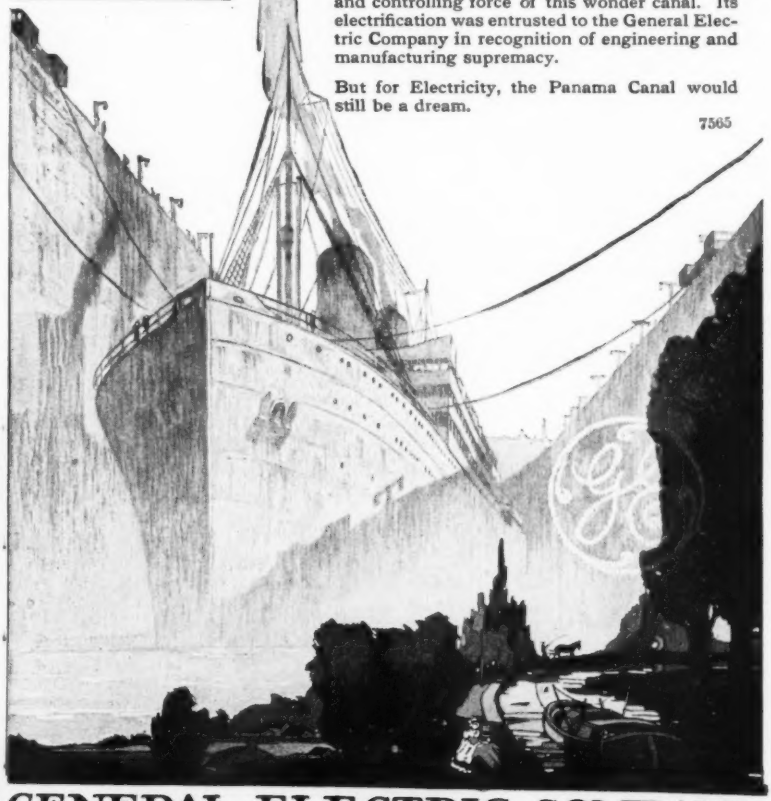

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The Bulletin is the official organ of the Society. It is published monthly from September to June. It contains not only the text of papers presented before the Society, but also college notes, short contributions from members, and matters of general interest to all persons connected directly or indirectly with technical education.

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